Sensing Target Handover in Integrated Sensing and Communication Systems

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***Abstract*—Integrated sensing and communication (ISAC) is a key feature of the fifth-generation advanced (5G-A) and sixth-generation (6G) mobile communication systems, enabling emerging applications with stringent communication and sensing requirements. ISAC allows a network to simultaneously detect and track sensing targets (STs) while providing communication services to connected devices. However, the mobility of STs poses challenges in maintaining reliable sensing performance. Tracking may be disrupted when an ST moves beyond the sensing entity's field of view, experiences degraded sensing conditions, or encounters line-of-sight blockages. To address these challenges, this paper describes the sensing-target handover procedures for three representative scenarios. The handover criteria and signaling procedures for handover request and acknowledgment exchanges between the sensing entities are presented and analyzed. A procedure-level latency model is derived to characterize a sufficient condition under which the sensing handover can be completed before the current sensing configuration becomes unusable. By dynamically transferring sensing responsibilities among sensing entities, the proposed handover procedures can support interruption-free target tracking and help maintain sensing performance in high-mobility ST environments.**

***Index Terms*—6G, ISAC, sensing-target handover, monostatic sensing, bistatic sensing**

I. Introduction

A. Integrated Sensing and Communication (ISAC)

The advent of new applications in 5G-Advanced and 6G such as autonomous driving, UAV transport, autonomous robots, to name but a few requires both advanced communication and sensing capabilities. As a result, a unified sensing and communication design is necessary to achieve the strict requirements of emerging applications and address spectrum scarcity due to the growing demand for wireless services.

Integrated sensing and communication (ISAC) aims to enable the spectral coexistence of sensing and communication by using a system with both communication and sensing functionalities. This system can simultaneously support the communication and sensing requirements of emerging applications while reducing the equipment's cost, size, energy consumption, and increasing spectrum efficiency. Furthermore, the mutual exchange of information between communication and sensing functions enhances the performance of both services.

B. ISAC standardization progress

The Third-Generation Partnership Project (3GPP) has identified five ISAC use cases for study: UAV detection and tracking, human sensing in indoor (e.g., room, office, factory) and outdoor (e.g., urban, rural) locations, automotive vehicles in urban and rural areas, automated guided vehicles in factories, the detection of hazardous objects (human and animals) on roads and railways [1]. The evaluation parameters for each use case have been defined to evaluate ISAC system designs.

To support ISAC performance evaluation, in Release 19, 3GPP has specified an ISAC channel model derived from existing communication channel models while incorporating sensing-specific characteristics such as location, Radar Cross-Section (RCS), polarization, etc. of one or more physical objects [1]. A physical object is categorized as a sensing target (an object of interest for sensing) (ST) or an environment object (a non-target object with known location). For a sensing transmitter (Tx)-ST link or ST-sensing receiver (Rx) link, the large scale and small scale parameters of the channel are obtained from the same communication scenario for Tx-Rx link unless ISAC-specific parameter modifications are explicitly defined.

3GPP initiated studies on waveform, frame structure for ISAC as well as integration aspects of sensing and communications for Release 20 in April 2026 [2].

In parallel with 3GPP activities, European Telecommunications Standards Institute (ETSI) has also conducted ISAC studies. 18 ISAC use cases have been identified that complement those specified by 3GPP [3]. Moreover, ETSI has investigated channel modeling aspects that are not addressed by 3GPP [4]. Beyond channel modeling, system and radio access network architecture study is conducted [5]. Furthermore, security, privacy, and sustainability aspects of ISAC systems have been studied to ensure the reliable and responsible deployment of sensing-enabled wireless networks [6].

C. Sensing-target handover problem in ISAC

The mobility of an ST poses challenges to maintaining continuous and reliable tracking. As the ST moves, it may leave the field of view of a sensing entity, rendering target tracking infeasible. Even in case the target remains in the field of view of the sensing entity, sensing performance may degrade as the distance between the ST and the sensing entity increases, resulting in a reduction in the power of the received reflected signal. In addition, the sensing entity may lose the line-of-sight (LOS) path to the ST when obstacles obstruct the propagation path between them. Therefore, an efficient ST handover (HO) mechanism is required to maintain reliable sensing and tracking performance in ISAC systems.

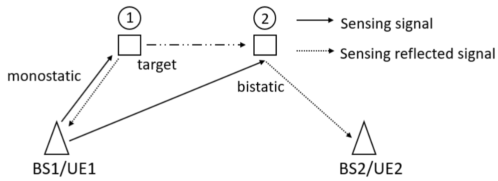

Fig. 1. Monostatic-to-bistatic-sensing handover.

The current 3GPP standard [7] specifies HO procedures only for communication scenarios, in which a serving base station (BS) transfers the communication service of a user equipment (UE) to a target BS to ensure service continuity. However, HO procedures for transferring sensing responsibilities between sensing entities have not yet been standardized.

[8] and [9] enhance sensing performance by simultaneously collecting measurements from multiple BSs and fusing the sensing data to obtain a more accurate estimate of the target. Unlike these cooperative sensing approaches, this work investigates ST HO procedures in ISAC networks. Instead of requiring multiple sensing entities to remain active simultaneously, the proposed handover transfers the sensing task from one sensing entity to another. Once the handover is completed, the original sensing entity can cease sensing operations while the target continues to be tracked by the new sensing entity.

This work studies ST HO procedures under different sensing modes. It reuses the existing NR interfaces and protocol frameworks developed for communication handover, including Xn application protocol (XnAP) and next generation application protocol (NGAP) to transport the proposed sensing-handover control messages. In addition, this work introduces new sensing-handover elements including the sensing-handover semantics and the sensing-specific information exchanged in the handover request and acknowledgment, such as the target state, sensing-resource configuration, sensing-signal configuration and beam configuration, that are not part of the currently standardized communication HO procedure. Section II examines monostatic-to-bistatic-sensing HO. Section III describes bistatic-to-monostatic-sensing HO. Section IV presents monostatic sensing HO. Section V analyzes procedure-level handover latency. Finally, Section VI concludes this work.

II. Monostatic-to-bistatic-sensing handover

Fig. 1 illustrates monostatic-to-bistatic-sensing handover. When the ST is in the 1^{st} position, the BS1/UE1 performs monostatic sensing to detect and track the ST by transmitting the sensing signal then receiving and processing the reflected signal to estimate the ST's range, velocity, angle of arrival (AoA) and trajectory. When the ST moves to the 2^{nd} position, the BS1/UE1 switches to bistatic sensing to continue to track the target. The BS1/UE1 transmits the sensing signal, while the BS2/UE2 receives and processes the reflected signal to estimate the target's parameters then sends this information to the BS1/UE1 (directly or indirectly via the sensing function) in a measurement report. The reference signal received power (RSRP) or sensing Signal-to-Interference-plus-Noise Ratio (SINR) of the reflected signal is also included in the measurement report so that the BS1/UE1 knows the quality of the received signal at the BS2/UE2. The handover procedure is illustrated in Fig. 2.

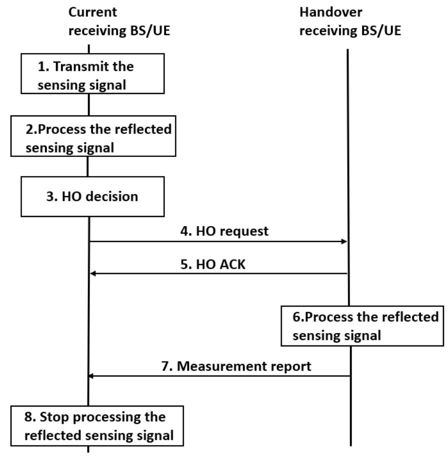

Fig. 2. Flowchart of monostatic-to-bistatic-sensing handover.

A. Transmission and processing of sensing signal before handover

In the first step, the BS1/UE1 transmits the sensing signal toward the target. In the second step, the BS1/UE1 receives and processes the reflected signal to determine the target's parameters and measure the reflected signal's power.

B. Handover decision

In the third step, the BS1/UE1 makes a HO decision based on the measurements derived from the reflected signal. The BS1/UE1 can use the following criteria to decide whether to carry out a handover from monostatic sensing to bistatic sensing as shown in Fig. 3.

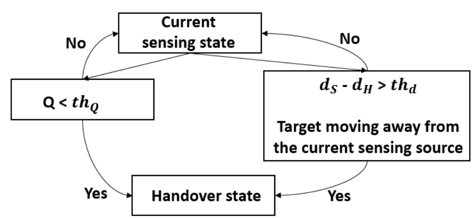

Fig. 3. Handover decision for monostatic-to-bistatic-sensing handover.

The reflected-signal RSRP or SINR may be used as the first quality metric. If the RSRP (or sensing SINR) of the reflected signal denoted Q is lower than its corresponding predetermined threshold (th_Q), the BS1/UE1 performs a monostatic-to-bistatic-sensing HO to maintain the sensing performance.

The second criterion is based on the target's trajectory and its distances from the current receiving BS/UE and the handover-receiving BS/UE. The distances from the target to the current receiving BS/UE (the BS1/UE1 in Fig. 1) and the handover receiving BS/UE (the BS2/UE2 in Fig. 1) are denoted d_S and d_H, respectively. When $d_S - d_H$ is larger than a predetermined threshold (th_d) and the target is moving away from the BS1/UE1, the BS1/UE1 initiates a handover. The BS1/UE1 senses the environment and employs positioning techniques to determine the relative positions of objects, UEs, and BSs in order to determine the handover receiving BS/UE.

The HO thresholds th_Q and th_d can be adjusted according to the target's velocity. At high speed, th_Q can be increased and th_d can be decreased to reduce handover latency. In contrast, th_Q can be decreased and th_d can be increased to avoid an early handover.

C. Handover request

In the fourth step, when the HO condition is met, the BS1/UE1 transmits a HO request to the BS2/UE2 by the methods defined in the following four scenarios.

For the HO request transmitted from the BS1 to the BS2, the HO request is transmitted directly from the BS1 to the BS2 over the Xn interface using the XnAP or indirectly through the core network (CN) where the BS1 transmits the HO request to the access and mobility management function (AMF) in the CN over the N2 interface using the NGAP. The AMF then forwards the HO request to the BS2.

For the HO request transmitted from the BS1 to the UE2 where the UE2 is already connected to the BS1 through the initial access procedure, the HO request is transmitted over the Uu interface via physical downlink control channel (PDCCH) and physical downlink shared channel (PDSCH).

For the HO request transmitted from the UE1 to the BS2 where the UE1 is considered to be in the same cell of the BS2 and connected to the BS2 through the initial access procedure, the HO request is transmitted over the Uu interface via physical uplink control channel (PUCCH) and physical uplink shared channel (PUSCH).

For the HO request transmitted from the UE1 to the UE2, the HO request can be directly transmitted to the UE2 over the PC5 interface via physical sidelink control channel (PSCCH) and physical sidelink shared channel (PSSCH) or if the UE1 and UE2 are within the coverage area of the same BS, the UE1 transmits the HO request to the BS over the Uu interface via PUCCH and PUSCH. Subsequently, the BS forwards the HO request to the UE2 via PDCCH and PDSCH.

The HO request includes the target's parameters, sensing resource indication and sensing-signal configuration enabling the BS2/UE2 to determine the sensing signal's time and frequency resources to receive and process the reflected sensing signal. In addition, the HO request indicates the configuration of Rx beam at the BS2/UE2. The BS1/UE1 determines the optimal Rx beam based on the target's trajectory, the relative positions of the BS1/UE1 and the BS2/UE2, allowing a reliable reception of the reflected sensing signal at the BS2/UE2. Furthermore, the HO request instructs the BS2/UE2 to send the measurement report back to the BS1/UE1.

D. Handover acknowledgment

In the fifth step, the BS2/UE2 transmits a HO acknowledgment (ACK) to the BS1/UE1 by the methods defined in the following four scenarios.

For the HO ACK transmitted from the BS2 to the BS1, the HO ACK can be transmitted directly from the BS2 to the BS1 over the Xn interface using the XnAP or the BS2 transmits the HO ACK to the AMF in the CN over the N2 interface using the NGAP. Then, the AMF transmits the HO ACK to the BS1.

For the HO ACK transmitted from the BS2 to the UE1, the HO ACK is transmitted on PDCCH and PDSCH.

For the HO ACK transmitted from the UE2 to the BS1, the HO ACK is transmitted on PUCCH and PUSCH.

For the HO ACK transmitted from the UE2 to the UE1, the HO ACK can be directly transmitted to the UE1 over the PC5 interface via PSCCH and PSSCH or if the UE1 and UE2 are within the coverage area of the same BS, the UE2 transmits the HO ACK to the BS over the Uu interface via PUCCH and PUSCH. Consequently, the BS forwards it to the UE1 via PDCCH and PDSCH.

The BS2/UE2 decides whether to accept the sensing HO request based on its battery/power status and its processing load from communication and/or sensing services. The BS2/UE2 may include the maximum sensing operation time in the HO ACK so that the BS1/UE1 knows the duration that the BS2/UE2 takes over the sensing process.

The HO request and ACK are also used to synchronize the clocks between the BS1/UE1 and the BS2/UE2 for the bistatic sensing after the handover.

If the BS2/UE2 rejects the sensing HO request, it transmits the HO non-acknowledgment (NACK) to the BS1/UE1 using the same signaling procedures and transmission methods as those specified for the HO ACK. Upon receiving the HO NACK, the current sensing BS/UE continues the sensing operation and selects another candidate sensing BS/UE according to the handover criteria in Section II-B. A new sensing HO request is then transmitted to the selected candidate.

E. Transmission and processing of sensing signal after handover

After accepting the sensing handover, the BS2/UE2 processes the reflected signal to estimate the target's parameters in the sixth step (the BS1/UE1 and the BS2/UE2 are synchronized to the accuracy required by the sensing waveform, and the BS2/UE2 knows the sensing waveform or sequence and its time-frequency configuration) then sends to the BS1/UE1 the measurement report in the seventh step.

The BS1/UE1 can continue to process the reflected signal until it receives the measurement report from the BS2/UE2 to support continuous tracking performance. Based on the measurement report, when the BS1/UE1 knows that the sensing performance is adequate at the BS2/UE2, it stops processing the reflected signal in the monostatic sensing mode in the eighth step. The handover procedure is completed.

III. Bistatic-to-monostatic-sensing handover

Fig. 4 illustrates a bistatic-to-monostatic-sensing handover. When the target is in the 1^{st} position, the BS1/UE1 performs bistatic sensing to detect and track the target. The BS1/UE1 transmits the sensing signal then the BS2/UE2 receives and processes the reflected signal to derive the target's parameters. Then, the BS2/UE2 transmits the measurement report to the

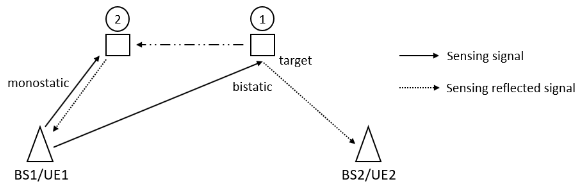

Fig. 4. Bistatic-to-monostatic-sensing handover.

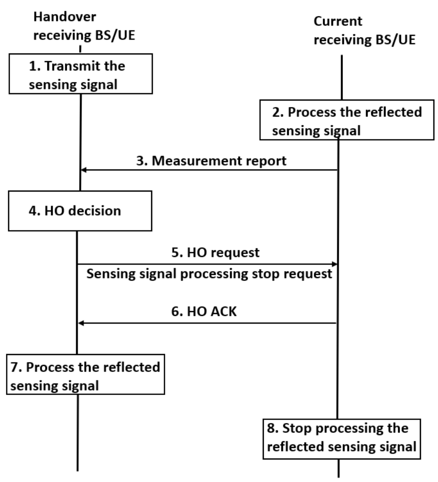

Fig. 5. Flowchart of bistatic-to-monostatic-sensing handover.

BS1/UE1. When the target moves from the 1^{st} position to the 2^{nd} position, the BS1/UE1 switches to monostatic sensing to track the target. The BS1/UE1 transmits and receives the sensing signal independently in order to estimate the target's parameters. The handover procedure is illustrated in Fig. 5.

A. Transmission and processing of sensing signal before handover

In the first step, the BS1/UE1 (the handover receiving BS/UE in Fig. 5) transmits the sensing signal toward the target. In the second step, the BS2/UE2 (the current receiving BS/UE in Fig. 5) receives and processes the signal reflected from the target to estimate the target's parameters and measure the reflected signal's power. Subsequently, in the third step, the BS2/UE2 transmits a measurement report containing the target's parameters and the reflected signal's RSRP or SINR directly or indirectly via the sensing function to the BS1/UE1.

B. Handover decision

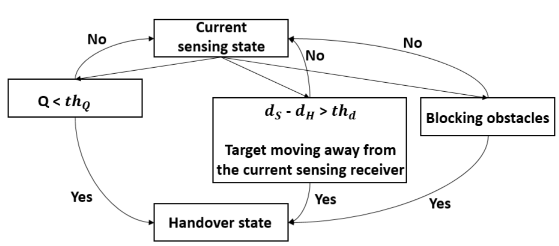

Fig. 6. Handover decision for bistatic-to-monostatic-sensing handover.

In the fourth step, based on the measurement report, the BS1/UE1 makes a HO decision according to one of the following criteria as shown in Fig. 6.

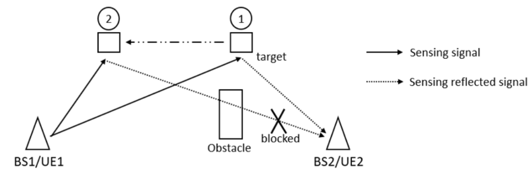

Fig. 7. Obstacle blocks the reflected signal in bistatic sensing.

The first criterion is the RSRP (or sensing SINR) of the reflected signal at the BS2/UE2. The BS1/UE1 performs a handover when the RSRP (or sensing SINR) denoted Q is lower than its corresponding predetermined threshold th_Q.

The second criterion is based on the target's trajectory and the distances between the target, the current receiving BS/UE and the handover receiving BS/UE. The distance between the target and the current receiving BS/UE (the BS2/UE2 in Fig. 4) is denoted d_S and the distance between the target and the handover receiving BS/UE (the BS1/UE1 in Fig. 4) is denoted d_H. When $d_S - d_H$ is larger than a predetermined threshold th_d and the target is moving away from the BS2/UE2 and towards the BS1/UE1, the BS1/UE1 initiates a handover.

The HO thresholds th_Q and th_d can be adjusted according to the target's velocity as explained in Section II-B.

The third criterion is based on the positions of obstacles in the environment. The BS1/UE1 senses the surrounding environment to determine the locations of nearby objects. Based on the target's trajectory, the BS1/UE1 can predict potential blockage of the reflected signal LOS path to the BS2/UE2 due to obstacles such as buildings as illustrated in Fig. 7. When the target moves to the 2^{nd} position, the BS1/UE1 determines that bistatic sensing with the BS2/UE2 as a receiver is no longer feasible because of the blockage. Consequently, the BS1/UE1 initiates a bistatic-to-monostatic-sensing handover to guarantee continuous target tracking.

C. Handover request

In the fifth step, after making a HO decision, the BS1/UE1 transmits a HO request to the BS2/UE2 to instruct it to stop processing the reflected signal on the time-frequency resources used by the sensing signal transmitted by the BS1/UE1 and cease sending the measurement reports. The HO request uses the transmission methods defined in Section II-C.

D. Handover acknowledgment

In the sixth step, the BS2/UE2 transmits a HO ACK to the BS1/UE1. The measurement report based on the latest received reflected signal may be included in the HO ACK so that the BS1/UE1 has the updated position and velocity of the target. The HO ACK uses the transmission methods defined in Section II-D.

E. Transmission and processing of sensing signal after handover

Upon receiving the HO ACK, the BS1/UE1 starts to process the reflected signal in the seventh step. After the sensing responsibility has been successfully transferred, the BS2/UE2 stops processing the reflected signal in the eighth step. The handover procedure is completed.

IV. MONOSTATIC-SENSING HANDOVER

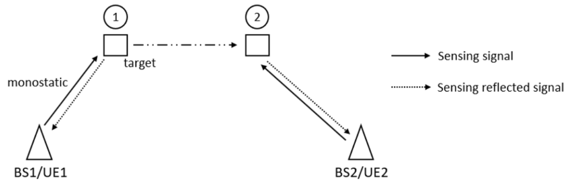

Fig. 8. Monostatic-sensing handover.

Fig. 8 illustrates a monostatic-sensing handover between the BS1/UE1 and the BS2/UE2. When the target is in the 1^{st} position, the BS1/UE1 performs monostatic sensing by transmitting the sensing signal and receiving the reflected signal to estimate the target's parameters. When the target moves to the 2^{nd} position, the BS2/UE2 takes over the sensing task, transmits the sensing signal and receives the reflected signal to estimate the target's parameters then transmits the measurement reports directly or indirectly via the sensing function to the BS1/UE1. After receiving this report, the BS1/UE1 stops transmitting the sensing signal. The HO procedure is illustrated in Fig. 9.

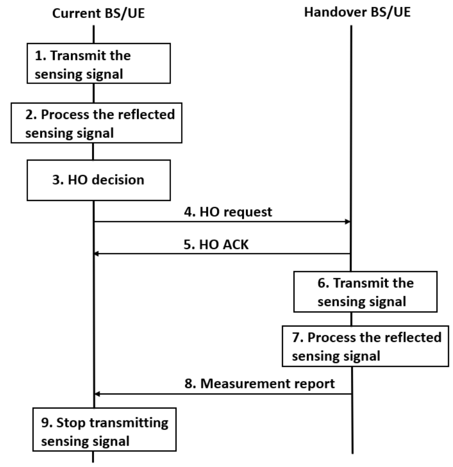

Fig. 9. Flowchart of monostatic-sensing handover.

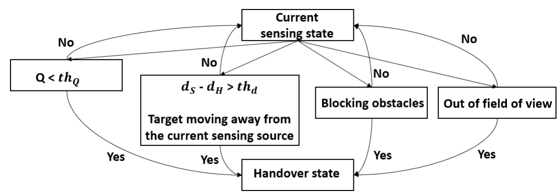

Fig. 10. Handover decision for monostatic-sensing handover.

A. Transmission and processing of sensing signal before handover

In the first and second steps, the current serving BS/UE (the BS1/UE1 in Fig. 8) transmits the sensing signal toward the target and receives the reflected sensing signal to estimate the target's parameters and measure the reflected signal's power.

B. Handover decision

In the third step, the BS1/UE1 makes a HO decision based on one of the following criteria as shown in Fig. 10.

The first and second HO criteria are the same as the criteria mentioned in Section II-B. The HO thresholds th_Q and th_d can be adjusted according to the target's velocity as explained in Section II-B.

The third criterion is based on the positions of obstacles in the environment. The BS1/UE1 locates nearby objects using sensing and positioning techniques. Based on the target's trajectory, the BS1/UE1 can predict potential blockage of the sensing signal transmitted to the target due to obstacles such as buildings, as illustrated in Fig. 11. Therefore, to ensure continuous target tracking, the BS1/UE1 hands over the sensing task to the BS2/UE2.

The fourth criterion is the field of view (FoV) of the BS1/UE1. When the BS1/UE1 predicts that the target will fly out of its field of view based on the tracked trajectory, it hands over the sensing task to another BS/UE whose FoV contains the target as illustrated in Fig. 12.

C. Handover request

In the fourth step, the BS1/UE1 transmits the HO request to the BS2/UE2 by the methods defined in Section II-C.

The HO request contains information about the target's location, velocity, and trajectory enabling the BS2/UE2 to configure the optimal transmitting beam of the sensing signal to illuminate the target. In the HO request, the BS1/UE1 also informs the BS2/UE2 to send it the measurement report.

D. Handover acknowledgment

In the fifth step, the BS2/UE2 transmits the HO ACK/NACK to the BS1/UE1 by the methods defined in Section II-D.

E. Transmission and processing of sensing signal after handover

The BS2/UE2 transmits the sensing signal toward the target and receives the reflected signal to estimate the target's param-

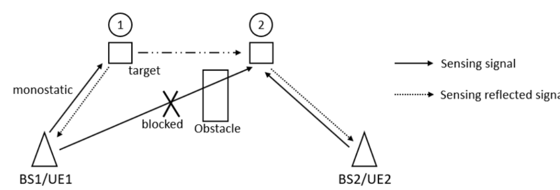

Fig. 11. Monostatic sensing blocked by an obstacle.

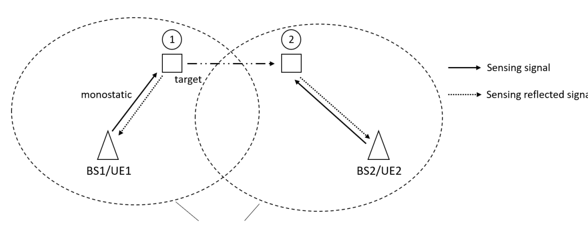

Fig. 12. Monostatic-sensing handover when the target is out of field of view of the serving sensing entity.

eters and track its movement in the sixth and seventh steps, respectively. This information is then sent by the BS2/UE2 to the BS1/UE1 in the measurement report in the eighth step.

After receiving the measurement report from the BS2/UE2, the BS1/UE1 stops transmitting the sensing signal in the ninth step. The handover procedure is completed.

V. Procedure-Level Handover Latency Analysis

The HO latency is defined as the time from the transmission of the HO request until the HO receiving entity obtains its first valid sensing measurement and, when required, the current sensing entity receives the corresponding measurement report.

For the monostatic-to-bistatic-sensing and monostatic-sensing handovers, the HO latency can be expressed as

$$T_{\mathrm{HO}} = T_{\mathrm{req}} + T_{\mathrm{adm}} + T_{\mathrm{ack}} + T_{\mathrm{cfg}} + T_{\mathrm{meas}} + T_{\mathrm{rep}}. \quad (1)$$

where T_{req} is the HO-request transmission latency, T_{adm} is the candidate admission-decision time, T_{ack} is the HO-ACK transmission latency, T_{cfg} is the configuration time of the handover receiving entity including the sensing-resource, sensing-signal, beam, and synchronization configurations, T_{meas} is the time required to obtain the first valid sensing measurement, and T_{rep} is the measurement-report latency.

For the bistatic-to-monostatic-sensing handover, the handover receiving entity already transmits the sensing signal and the first post-handover measurement is locally available. Therefore, neither a candidate admission decision nor a measurement report to the same entity is required, and the corresponding latency is

$$T_{\mathrm{HO}}^{\mathrm{B2M}} = T_{\mathrm{req}} + T_{\mathrm{ack}} + T_{\mathrm{cfg}} + T_{\mathrm{meas}}. \quad (2)$$

Equations (1) and (2) assume successful HO signaling without message retransmissions. In (1), if the request is rejected, the candidate-reselection delay, NACK transmission latency, and latency of an additional request-response exchange are added to the total HO latency.

The predicted remaining time before the current sensing configuration becomes unusable is

$$T_{\mathrm{avail}} = \min\left\{T_{\mathrm{quality}}, T_{\mathrm{distance}}, T_{\mathrm{LOS}}, T_{\mathrm{FoV}}\right\}. \quad (3)$$

In (3), T_{quality} is the predicted remaining time until the reflected-signal quality becomes insufficient, T_{distance} is the predicted remaining time until the target reaches the maximum distance or geometric limit supported by the current sensing configuration, T_{LOS} is the predicted remaining time until the LOS path is blocked, and T_{FoV} is the predicted remaining time until the target leaves the field of view of the current sensing entity. Only the failure mechanisms applicable to the considered sensing scenario are included in the minimum.

A sufficient condition for interruption-free handover is

$$T_{\mathrm{HO}} \leq T_{\mathrm{avail}}. \quad (4)$$

The potential tracking-interruption duration can consequently be approximated as

$$T_{\mathrm{int}} = \max\left\{0, T_{\mathrm{HO}} - T_{\mathrm{avail}}\right\}. \quad (5)$$

For a target moving toward the limiting sensing boundary with a constant boundary-approach velocity $v_b > 0$ and a remaining path-distance margin D_m, the remaining usable sensing time is

$$T_{\mathrm{avail}} = \frac{D_m}{v_b}. \quad (6)$$

Combining (4) and (6), the HO should be initiated such that

$$D_m \geq v_b T_{\mathrm{HO}}. \quad (7)$$

When a guard time T_g is introduced to account for latency uncertainty and target-trajectory prediction errors, the triggering condition becomes

$$D_m \geq v_b \left(T_{\mathrm{HO}} + T_g\right). \quad (8)$$

(7) and (8) show that a higher target velocity requires a larger remaining sensing margin when the HO is initiated.

VI. Conclusion

This paper presented handover procedures for sensing targets in ISAC systems. Three sensing-target handover scenarios were investigated: monostatic-to-bistatic-sensing handover, bistatic-to-monostatic-sensing handover, and monostatic-sensing handover. For each scenario, detailed signaling procedures were specified, including handover criteria, handover request and acknowledgment signaling between sensing entities. The corresponding transmission and signal-processing operations before, during, and after the handover were also described. A procedure-level latency model was derived to relate the HO latency to the remaining usable sensing time. The proposed handover procedures can support interruption-free sensing-target tracking and reliable sensing performance in the presence of sensing-target mobility. By allowing sensing operations to be dynamically transferred among sensing entities, the proposed framework improves the reliability and robustness of ISAC systems when sensing targets move beyond the sensing coverage area, experience degraded sensing conditions, or encounter line-of-sight blockages. Therefore, sensing-target handover represents an important mechanism for supporting mobility management in future 5G-Advanced and 6G ISAC networks.

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